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## TREATMENT OF LARGE RESERVOIRS WITH ALUM TO REDUCE TURBIDITY

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SANITARY ENGINEERING DIVISION

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# TREATMENT OF LARGE RESERVOIRS WITH ALUM TO REDUCE TURBIDITY

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The normal desire of the water works operator to supply the consumer with an aesthetically satisfactory product, which is noncommittally accepted without consideration of the problems of production, is occasionally circumvented by circumstances beyond the control of the omniscient operator. When the water quality factors of taste, odor, and appearance pass the critical limits acceptable to the consumer, reaction is quick and vociferous. Under such circumstances, drastic action is sometimes required to attack unusual problems produced by an emergency. The Sanitary Engineering Division of the Department of Water and Power of the City of Los Angeles was presented with an emergency problem of producing an acceptable supply from badly roiled reservoirs caused by severe storms in January and March of 1952 with inadequate treatment facilities to cope with this unusual condition. With little background experience on which to operate, two of the most critical storage reservoirs were treated with aluminum sulphate in an effort to produce a usable supply from a source described as almost too thick to flow and yet too thin to plow.

The water supply of the City of Los Angeles is furnished by an extensive collecting, conveyance, and distributing system. The major portion of the supply (75% to 80%) is derived from snowfall in the Sierra Nevada Range bordering the Owens River Valley, some 250 miles to the north. This water supply is developed in a semi-arid region. On the way to Los Angeles, it passes through two large reservoirs in the desert and enters the City of Los Angeles at the north end of San Fernando Valley, about 25 miles from the Civic Center.

Inasmuch as the watershed of the Owens River is almost entirely desert with little rainfall, there is a minimum of turbidity present in the water throughout the major portion of the year. During the spring runoff the turbidity in the Owens River may increase considerably, but this usually settles out in passing through Haiwee and Fairmont Reservoirs with approximately 59 days' and 7.6 days' retention, respectively. During the remainder of the year what little turbidity is present is due mainly to algae and seldom exceeds 5 p.p.m. Treatment of the Los Angeles water supply is limited to chlorination before distribution and periodic reservoir treatments with copper sulphate for algae control.

About 35 miles north of Los Angeles, there is a wide spot in the aqueduct known as Dry Canyon Reservoir. This has a very limited retention and serves more as a regulatory reservoir for power operation. Dry Canyon

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Reservoir is occasionally subject to flash floods at which time it is removed from service for a day or two after which the turbidity generally does not exceed 12 p.p.m.

On entering the San Fernando Valley, the water passes through Upper and Lower San Fernando Reservoirs. Upper San Fernando Reservoir has a capacity of 1,848 acre feet, and Lower San Fernando Reservoir has a capacity of 20,500 acre feet, giving normal theoretical retention of 2.6 days and 28 days, respectively. Upon leaving San Fernando Reservoir, the water is carried by three main trunk lines across San Fernando Valley, serving the local demand in this area and passing through the Santa Monica Mountains into three major reservoirs on their south slopes for distribution to the City proper. These reservoirs, from west to east, are Stone Canyon, capacity of 7,998 acre feet; Lower Franklin, capacity of 1,030 acre feet; and Lower Hollywood, capacity of 4,036 acre feet.

Upper and Lower San Fernando Reservoirs are partially protected against local storm runoff. In 1940 diversion works and debris basins were constructed on the west side of these two reservoirs which provided for the diversion of major storm flows. The flood diversion works were designed so that storm runoff in excess of 200 second feet would fill the debris basins and overflow into the lower reservoir. There is one large drainage channel, Bledsoe Wash, directly entering Lower San Fernando Reservoir on the northeast side.

Of the three major reservoirs south of the Santa Monica Mountains, Lower Hollywood Reservoir is completely protected against storm water runoff. Lower Franklin Reservoir has storm diversion works on the west side of the reservoir, taking all storm water runoff above and to the west of the reservoir. On the east side there is a very limited watershed covered with natural chaparral. Stone Canyon Reservoir has no storm diversion works, and all runoff from its 1.36 square miles of watershed drains directly into the reservoir. This watershed is covered with native chaparral and contains no habitation at present. Unfortunately, the City of Los Angeles does not own the entire watershed of many of its reservoirs.

Within the past few years, realty promoters have opened numerous subdivisions, particularly on the east side of Lower Franklin Reservoir and on the south and west sides of Stone Canyon Reservoir. These subdivisions were at the crest of the watershed, and development work included cutting off many hill tops to make building sites and roads. The waste material was not compacted in fills, but was merely bulldozed down the slope, assuming its natural angle of repose.

Following the winter of 1943-44, which was slightly above average in rainfall, a series of years of very subnormal rainfall occurred. The winter of 1951-52, however, with a seasonal total of 24.63 inches of rainfall by the end of March, was considerably above the normal of 13.73 inches for that period and caused considerable damage to unconsolidated fill material in many locations in Southern California. The heavy rainfall saturated the loose fill material, and following a very prolonged rain between January 12 and 18, 1952, this material flowed like mud. An estimated 2,850 cubic yards were washed into Lower Franklin Reservoir and its marginal area, and approximately 7,700 cubic yards were washed into Stone Canyon Reservoir and its marginal area. This heavy rainfall raised the turbidity in Dry Canyon Reservoir from 8 p.p.m. to over 200 p.p.m. The reservoir was shut off and drained to eliminate the excessive turbidity. Bledsoe Wash and overflow from the debris basin contributed a very heavy load to Lower San Fernando

Reservoir, causing turbidity of the outlet to rise to 80 p.p.m. on January 20, 1952. By operational changes at Lower San Fernando Reservoir, this heavy load of turbidity was somewhat reduced, and water served San Fernando Valley area did not exceed about 22 p.p.m. after the first day or two of the storm.

The storm of January 1952 caused exceptionally high turbidity in both Stone and Lower Franklin Reservoirs due to the heavy erosion of uncompacted fills. Turbidities rose from 5 p.p.m. to about 60 p.p.m., and complaints of dirty water flooded the offices. With a weekly average of 72 complaints for the same period the previous year, a peak of 3,274 complaints were received in one week following the storm. Neither Stone nor Lower Franklin Reservoirs could be by-passed, and it was impossible to avoid using this highly turbid water.

In two prior storms many years ago when two smaller reservoirs developed turbidity exceeding 2,000 p.p.m., alum had been added and the turbidity reduced to less than 100 p.p.m. in 24 hours. No other Department reservoirs had ever been treated in this manner before, and it was uncertain whether it could successfully be done in large reservoirs. Jar tests were made of the water from both Stone and Lower Franklin Reservoirs. In running the jar tests, a very minimum of stirring was given the water in an effort to simulate the actual field conditions of the reservoir treatment. A dose of 5 grains per gallon of alum was tentatively determined to be satisfactory, and arrangements made to treat the reservoirs. Consideration was given to ferric chloride as it gave a much heavier floc with a lower dose. This was discarded in favor of alum because of difficulties in handling.

Chemical companies were contacted, and it was found that 70 tons of powdered filter alum were immediately available in Los Angeles. Thirty tons were delivered to Lower Franklin Reservoir, and 40 tons delivered to Stone Canyon Reservoir. It was realized that the amount for Stone Canyon Reservoir was less than desirable, but it was thought that the lower amount might do some good, and it was very desirable that action be taken rapidly as possible.

On the evening of January 23, 1952, treatment of Lower Franklin Reservoir was started. The reservoir is about 400 feet wide, 3,300 feet long, and 32.52 acres in area. Water entering the reservoir passes through a power house, the tailrace of which is connected to a large pipe with multiple outlets along the bottom of the reservoir distributing water throughout the length of the reservoir. Alum was dumped directly into the tailrace to distribute some throughout the reservoir. Although a fair distribution resulted, operational difficulties resulting from dusting caused by the tailrace up-draft and lack of protective equipment, soon discouraged much activity at that point. Reservoir treatment was conducted using a large rowboat and a plywood boat with outboard motors. A boat operator and two laborers were assigned to each boat which had capacity for about one-half ton of alum. Procedure was to pour the alum into propeller wash at the rate of a sack a minute, starting at the lower end of the reservoir and working up the reservoir in sections. Operations were handicapped throughout the night as the work progressed. The small boat began to break up due to overloading and was put out of commission. In addition, the heavier outboard motor became fouled with alum in the ignition system and was retired for the night. However, one boat was operated the entire night. The next morning another boat with an inboard motor was obtained, and treatment concluded by evening.

Results of this treatment were satisfactory considering the crude method of application and difficulties encountered. Observation showed a good floc

formation for the treatment which amounted to about 5 gr/gal. for the upper 10-foot stratum. Effects were noticeable the morning after treatment was started, and by the second morning turbidity had been reduced from 54 p.p.m. to 14 p.p.m. at the outlet, as shown on the graph (A) of Lower Franklin Reservoir turbidities. Cost of this treatment was about $2,700 with cost of alum delivered varying from $42.00 to $50.00 per ton, depending on source of supply.

Effectiveness of the treatment at Lower Franklin Reservoir encouraged a more extensive treatment at Stone Canyon Reservoir than originally planned. Stone Canyon Reservoir with a very irregular shoreline is approximately 5,500 feet long and had a surface area of 117 acres at time of treatment. At 9 A.M. on January 28, 1952, a 70-ton treatment was started and completed by midnight. Experience gained at Lower Franklin Reservoir facilitated operations. This operation was also better equipped in that the regular Stone Canyon Reservoir beat with a 2,000 pound load capacity was available in addition to the two boats used at Lower Franklin Reservoir. This treatment of 2.46 gr/gal. in the upper 10-foot stratum, although less than the optimum 5 gr/gal. dosage, gave satisfactory results. Turbidity was reduced to about 20 p.p.m. within 24 hours and down to about 16 p.p.m. the second day. As shown on the graph (B) of Stone Canyon Reservoir turbidities, the upper stratum clarified reasonably well down to the first gate level at about 18 feet; but results at the next gate at 49 feet were much slower. Since distribution demands exceeded the capacity of the first gate level, it was necessary to supplement the supply by drawing also from the 49-foot level. This produced higher turbidities at the outlet than if only the upper level had been used. One week after treatment, there was an increase in turbidity in the upper level of the reservoir caused by wind action mixing water from the lower levels after which turbidity slowly decreased throughout the reservoir. The treatment of Stone Canyon Reservoir, costing about $4,700 helped considerably in relieving pressure from consumer complaints.

One difficulty experienced subsequently at Stone Canyon Reservoir was that the inlet water from San Fernando Reservoir still had a turbidity between 20 and 25 p.p.m., thereby reducing the beneficial results of the reservoir treatment. Some difficulty was also experienced due to the fact the inlet water at Stone Canyon Reservoir flowed down a natural, stabilized channel from the tunnel outlet. Construction work in the vicinity of the tunnel outlet had deposited some earth in the bottom of the channel which further increased the turbidity of the inlet water. To offset this, alum was added to the water at the tunnel outlet. About five tons over a period of thirteen hours were used and aided considerably in clarifying the water entering the reservoir.

Following the January storms, February had little rain; March, however, came back with a heavy rainfall of 2.52 inches on the 6th and 7th and 2.03 inches on the 15th. This caused additional high turbidity in Franklin Reservoir which was treated again on March 18, 1952 with 40 tons of alum. This treatment reduced the outlet turbidity from 36 p.p.m. to 12 p.p.m. at a cost of $2,550 and was considered to be well worth the cost.

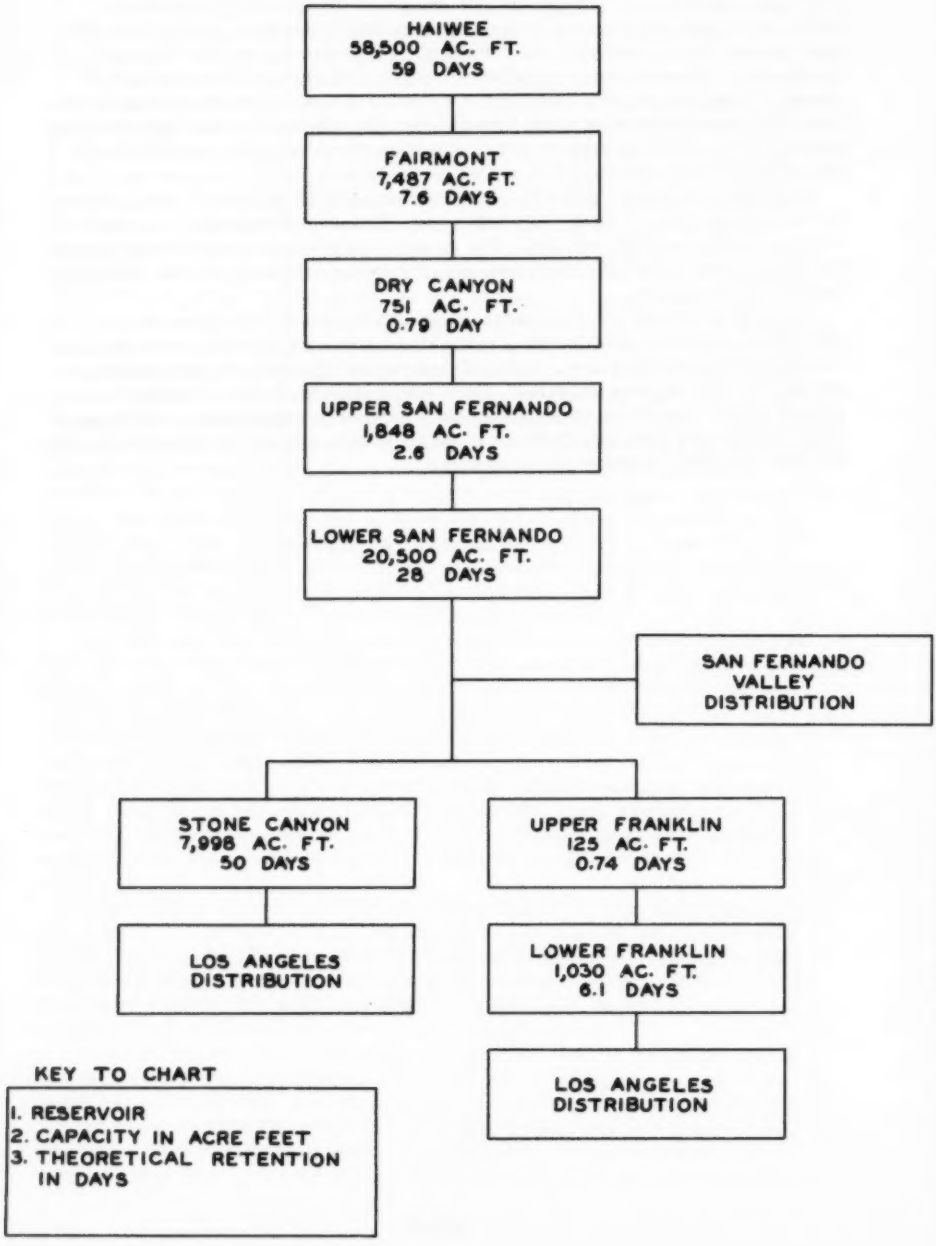
Construction work on a new high service reservoir at the upper end of Stone Canyon during the year of 1952 produced large areas of exposed earthwork and embankment. The early indications promised a wet year for the rainy season of 1952-53, which failed to materialize, and a subnormal season resulted. However, in anticipation of a repetition of the winter of 1951-52, preparations were made for more effective handling of alum had reservoir

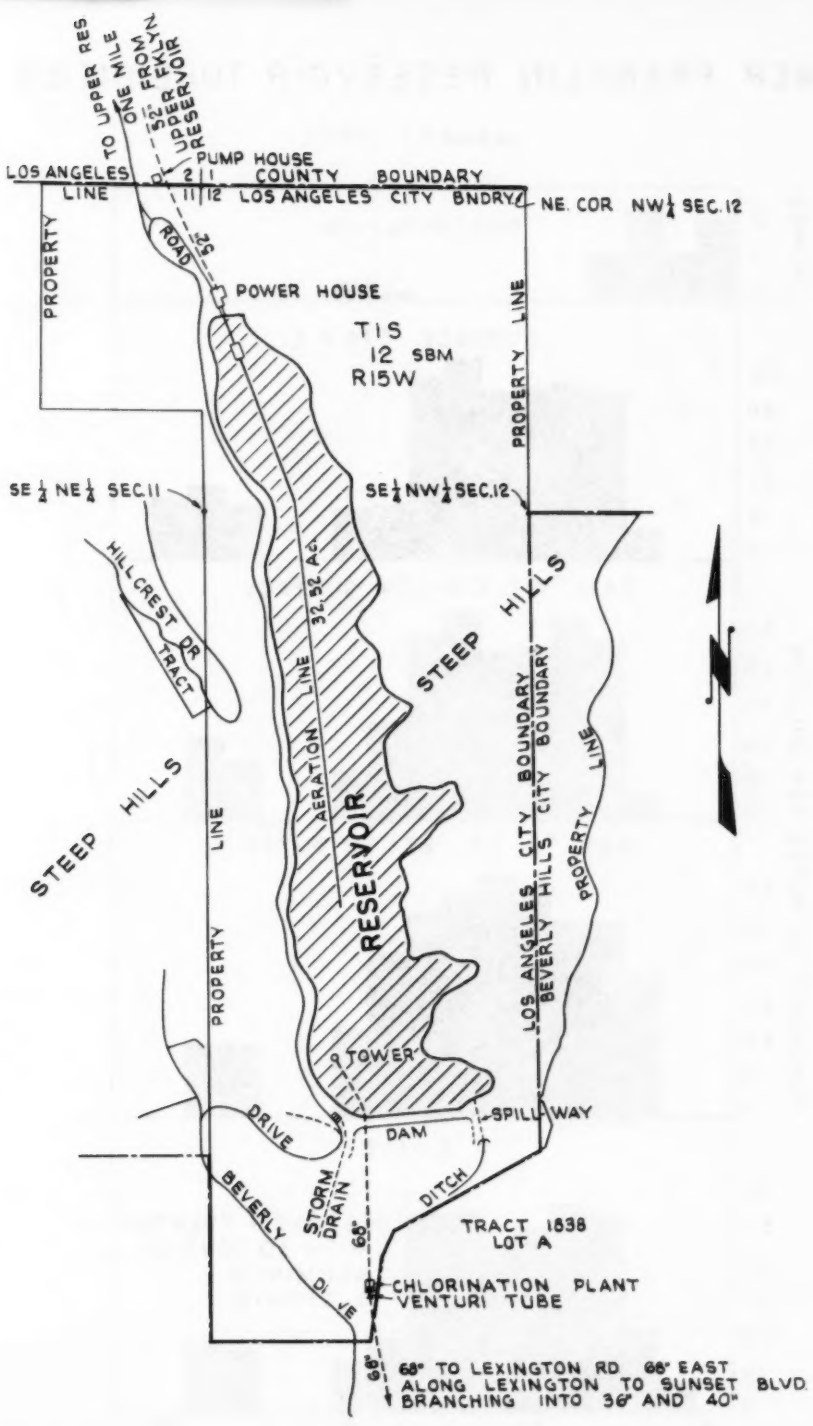
treatment become necessary. Two machines were constructed to distribute alum from boats more efficiently. Experience showed that the blower method of distribution used by the Division for copper sulfate treatments was not adaptable to powdered alum. The new machines are continuous belt feeders which can handle from 1.2 pounds per minute to 200 pounds per minute. These machines are capable of treating with heavy dosages, and reduce the dust hazard which produced eye irritations prevalent during the original treatments. Experimental installations were also set up to treat drainage channel flows before they entered the reservoirs. Although the necessity to treat any reservoirs with alum failed to develop, the continuous belt chemical feeders were used for copper sulfate treatments on several reservoirs and proved to be very effective for winter algae growths.

Construction plans for the Department during 1953 included bypass lines for both Stone Canyon Reservoir and Lower Franklin Reservoir. Storm diversion works are not included. The completion of these projects will permit the reservoirs to be removed from service should critically turbid conditions develop in the future.

The experience in treating large excessively turbid reservoirs with aluminum sulfate to ameliorate a critical condition showed this method to be a useful palliative measure. Although not highly efficient, results justified the efforts and expense required. However, our experience indicates that proper storm diversion works effectively protect the reservoirs, and bypass lines and proper gate installations in outlet towers permit the distribution of the best available water to the consumer.

# HEMATIC FLOW DIAGRAM OF RESERVOIRS THE OWENS VALLEY SUPPLY SYSTEM

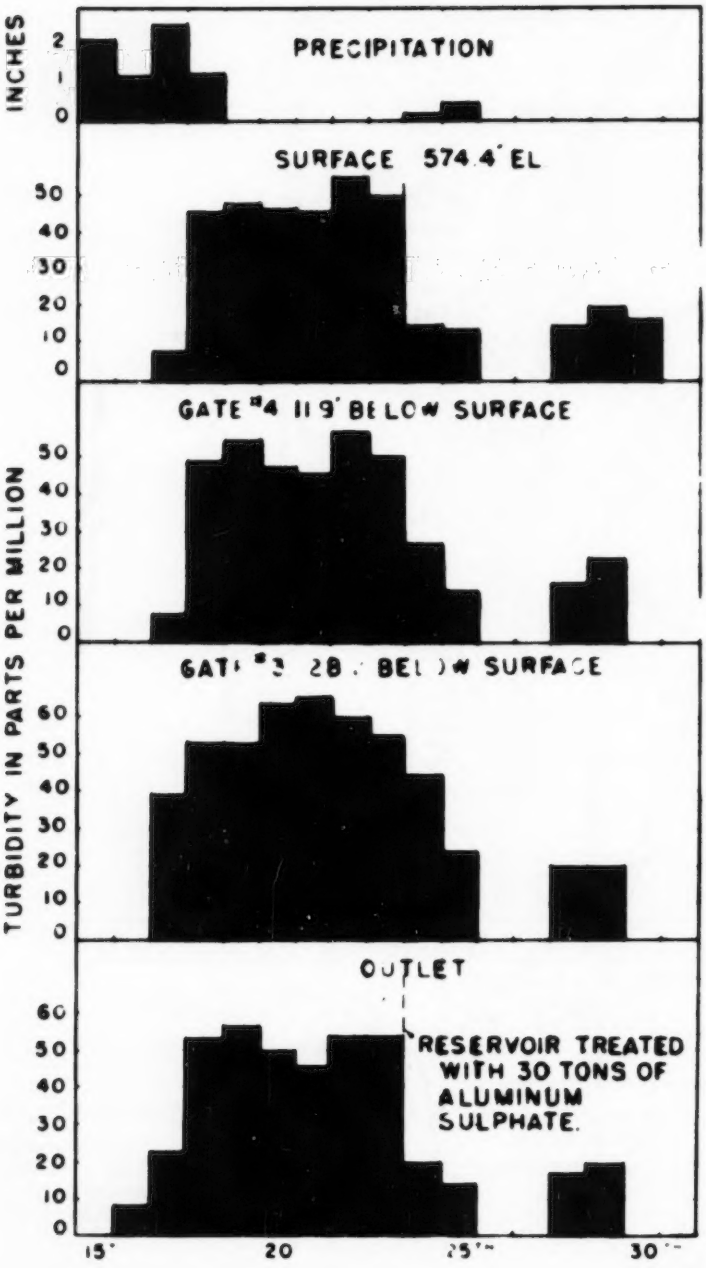





# LOWER FRANKLIN RESERVOIR

# LOWER FRANKLIN RESERVOIR TURBIDITIES

JANUARY 1952

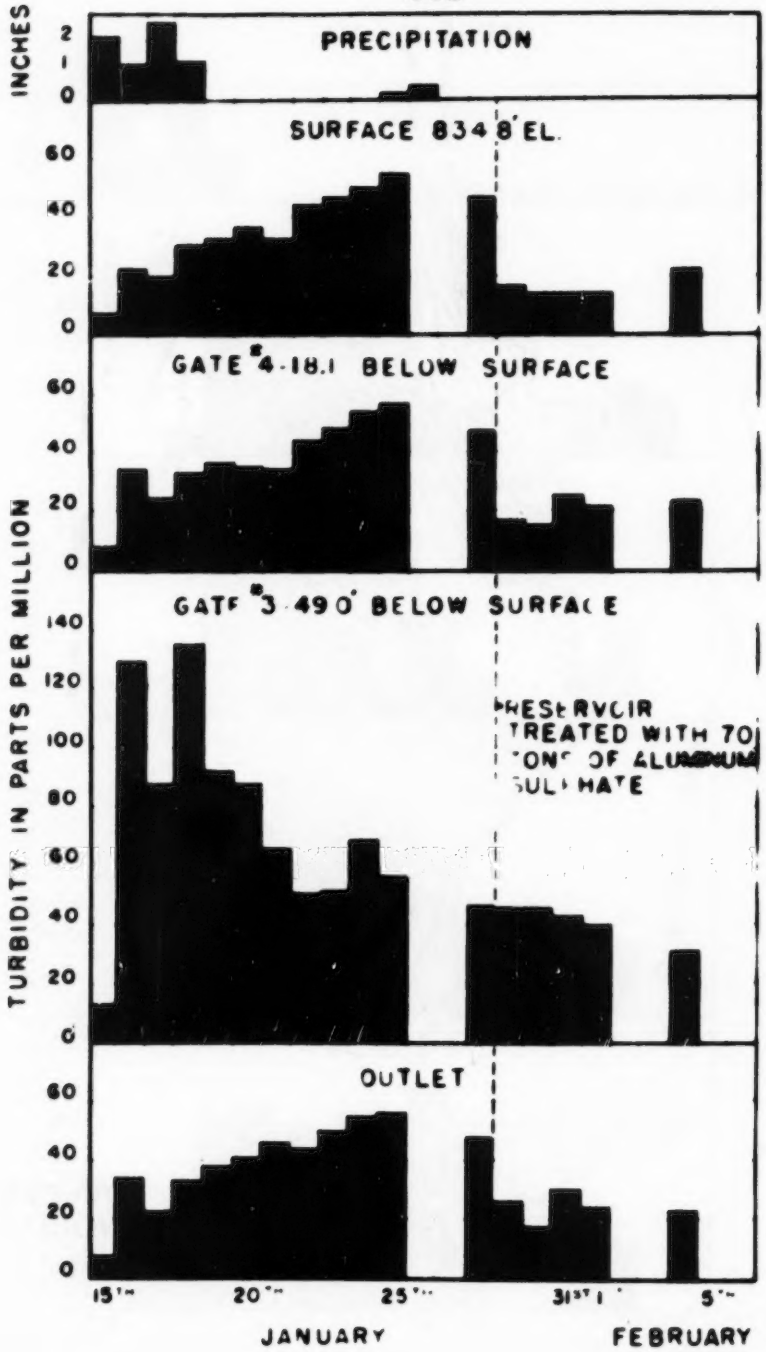



GRAPH -A

# STONE CANYON RESERVOIR

# STONE CANYON RESERVOIR TURBIDITIES

1952




GRAPH-B

Fig. 6. Stone Canyon Reservoir showing typical subdivision work

Fig. 7. Mud deposits from fills at Stone Canyon Reservoir

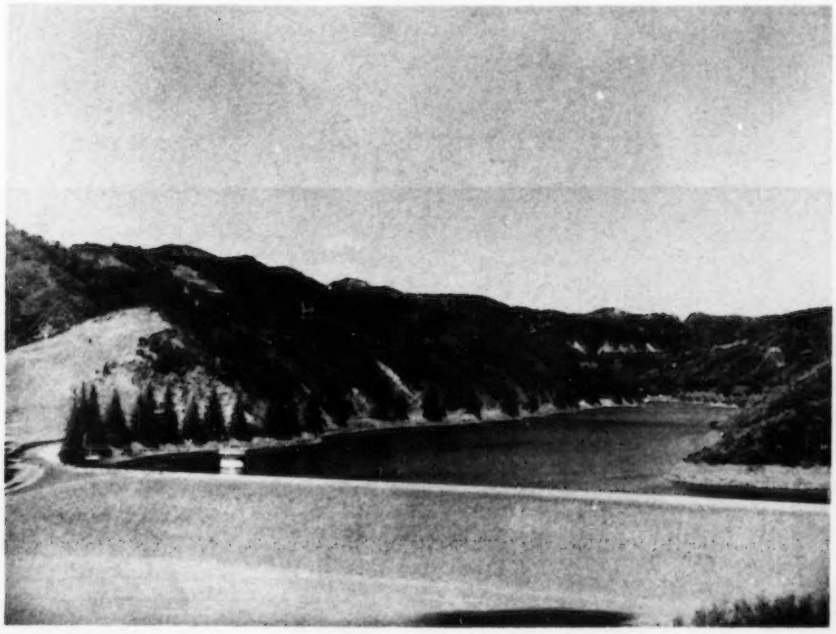


Fig. 8. Lower Franklin Reservoir

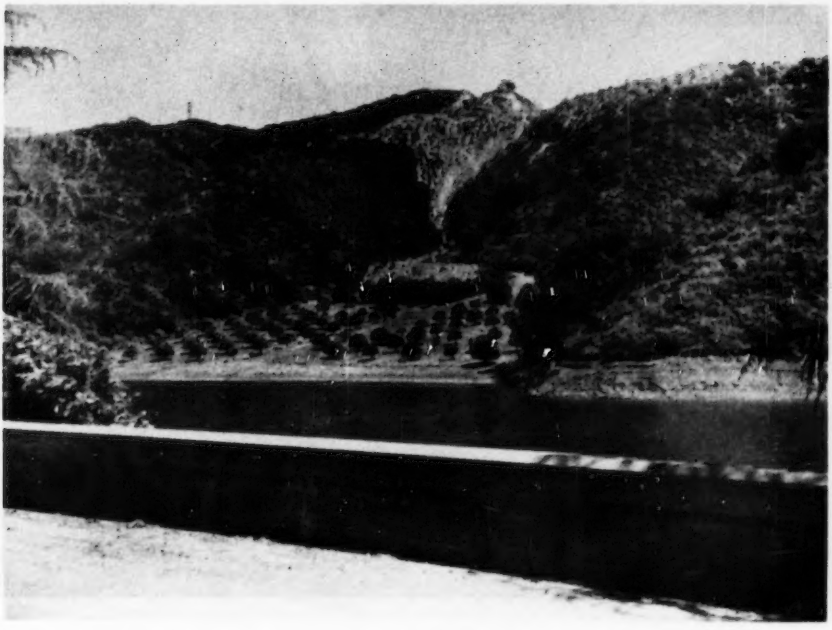


Fig. 9. Loose fills on east ridge of Franklin Canyon

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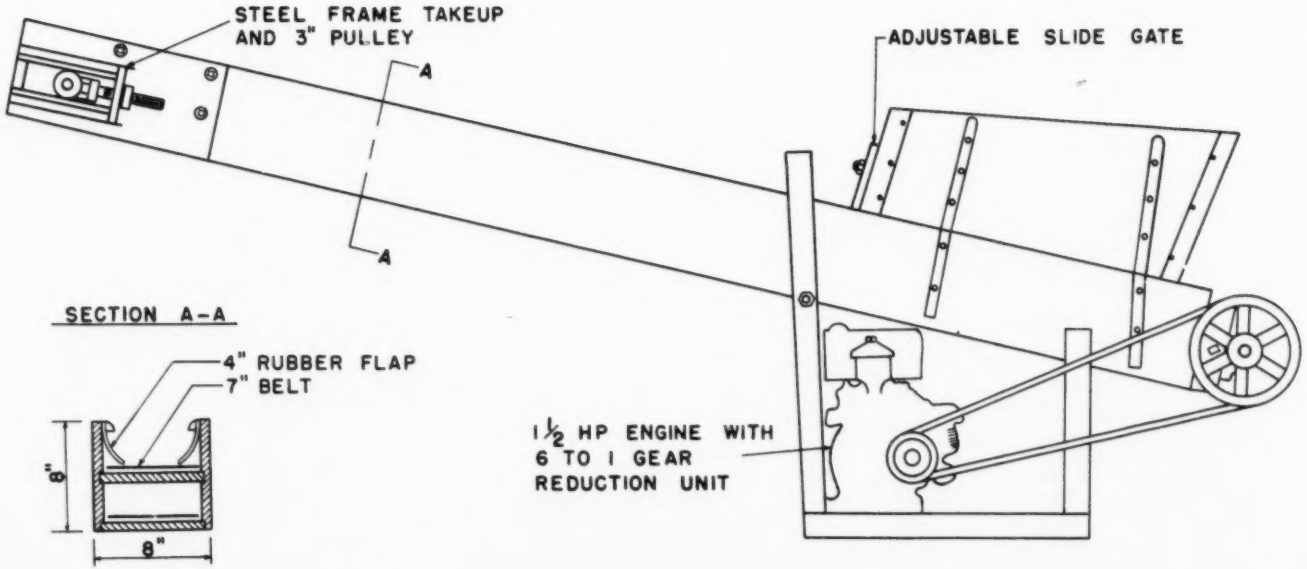
Fig. 10. Reservoir treatment with chemical feeder

# SKETCH OF BELT CONVEYOR CHEMICAL FEEDER

NO SCALE

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